VIRTUAL BATCH MANUFACTURING

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Abstract: This paper describes a possible way to create digital twin of a batch production process. This virtual model of the batch system can be used for testing ISA-88 and ISA-95 with a virtual or real PLC without real system. There is also a possible use for education in labs with PLCs to show a behavior of a batch actors (valve, mixer, heater etc.) and ways to control, which can be tested in the virtual manufacturing system.

Keywords: ISA-95, ISA-88, Siemens, PLC, Step7, C#, Virtual manufacturing, Industry 4.0

1 INTRODUCTION

Virtual manufacturing embodies one of the pillars of Industry 4.0. Thus, a real system can be measured and observed to create a virtual model of a system. In terms of the production flow continuity, the manufacturing cycle comprises three main parts:

- discrete production;
- continuous production;
- and batch production.

This paper discusses batch production, mainly due to the present necessity to modernize tutorials focusing on batch control processes. The ISA-88 standard characterizes the requirements for batch control, namely, the software implementation rules. The requirements include three models, and these are described within the present paper.

Currently, almost all processes are controlled by a MES (Manufacturing Execution System). The ISA-95 defines the interface between process control and an execution system. An illustrative example of production with MES can be seen in a batch processes during the manufacturing of fruit juice. A PLC program is equipped with device control and functions (phases) for the MES. A process engineer does not need to know the operational principles of the given device: he or she is only required to possess knowledge of how the phases are organized in consecutive order.

A PLC programmer should be proficient in all the standards, and they are also expected to have the ability of testing their program. Using a virtual batch simulator, it is possible to create a debugged control program and test cooperation with the MES.

2 VIRTUAL MANUFACTURING

In a virtual model of a system (such as a manufacturing line or a robotic stand), any variation can be simulated before the real change; the programmer is then able to change and test a new program.

Thus, the time otherwise spent on program debugging is saved, and the costs manufacturing cycle termination can be fully eliminated. If there is the possibility that a manufacturing line produce another item with same mechanical parts, the virtual model enables us to test and prepare the modifications without the need to shut down the assembly line.[6] Alternaltively, we can create the virtual model before the real system, with the programmer being able to set up the control software of the entire system before the actual realization. The whole system can be tested, facilitating the prevention of most errors affecting the system control procedure.[6] The final price of the real system can be minimized in this manner, and the virtual testing will cancel out a subnstantial part of the adjustments and revisions.

Creating the virtual model of system has some dissadvantages. The firts one is a price of a softwares for a virtual manufacturing. The second one is that the engineer which can use this software are not cheap too. And last one is a difficulty of this software, this is caused by lot of modification and possibilities of softwares. Because of that using this softwares can cause an irreversible costs for a small or medium firms.

2.1 Virtual manufacturing softwares

A huge number of a firms which creates a components for an industry and wants to go hand-in-hand with the idea of Industry 4.0 creates virtual manufacturing software.

Mostly known softwares are Tecnomatix, Process Simulate, SIMIT (Siemens), Delmia (Dassalut Systemes), RobotStudio (ABB), KUKASim (KUKA AG), ESI-Group softwares with a modules for a welding, assembly, metal sheet forming etc. A user base is not big, and an experience forums as well, so first steps with these softwares could be difficult.[6]

3 VIRTUAL BATCH MANUFACTURING APPLICATION

Finding a possibilities of creating virtual batch manufacturing cell, invoke an idea to program an own single-celled application to simulate the batch process. In PLC laboratory in BUT, there are Simatic S7-1512 PLCs. So main idea was to create the simulator which will look like a real system for a PLC. The application needs to read PLC outputs and write PLC inputs. This could be achieved by two possibilities. Using a Modbus protocol, which can read and write an input/output registers or coils, can be achived that a virtual system will be like a real system for the PLC. This possibility was not good because of a declaration Modbus communication in PLC and this was not desirable for education excercises. The other choice was Step7 protocol. This protocol is natively implemented in the Siemens PLCs, with this protocol can be loaded a program from a PG station or a PLC can communicate to an another station. A main advantages are, that only enabling this communication in a hardware configuration is all what has to be configured in a PLC and this protocol can write to an input area and read an output area of a PLC.

The communication library of Step7 was created by Davide Nardella and published for free.[8] There is a various programming languages in which is implemented this protocol. Because of choosing this communication method, there is a limitation to communicate only with Siemens S7 PLCs.

3.1 Application implementation

The virtual model of the batch system (see in Figure 1) is consist of one tank with a filling and draining valves, mixer and heating element. This Windows form application sends data to the PLC and read from PLC. A bahaviour of this system can be seen in the visualization window Figure 1. The valves and mixer is controled only by a digital output and after switching on an engine there is a feedback from a contactor and in case of the valves, there is a feedback from end sensors. The tank can be filled to defined liquid level and this mass of liquid can be heated to defined temperature. In the application is described a thermal capacity of liquid and created a real system which can be regulated with the heater to a requested temperature. The heater has analog output, so it is possible to regulate heat power.

For a PLC program is required to identify and find a constants of this system. Education purposes of this application can show students how they can use Siemens TIA Portal to identify this system, and after that create a regulator to control the temperature.

To simulate a real system there need to be a possibility to create a malfunction of system. By clicking on element in application can be invoke a malfunction which is signalized as PLC input. The control system should react on the malfunction and all malfunction states can be simulated, tested and processed.

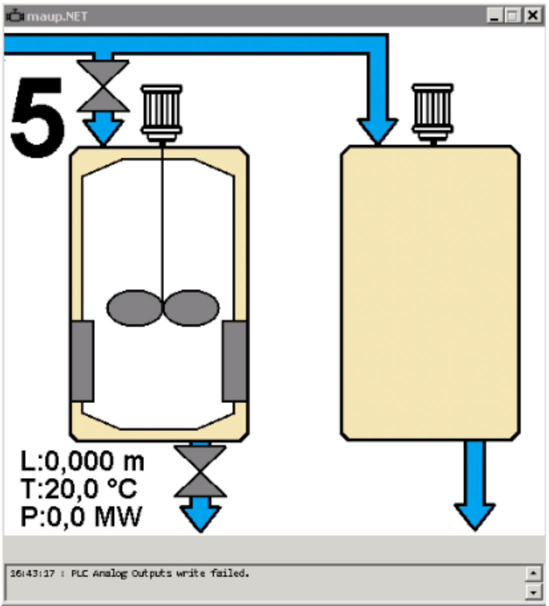

Figure 1: The visualization window of a virtual batch manufacturing application in Windows Forms, written in the C#.

4 ISA-88

The standard ISA-88 describes three models:

- process model,
- physical model,
- procedural control model.

Process model is not connected to any particular device but defines the whole process from the point of view of individual process events. The hierarchy of steps can be seen in Figure 2. The process action is the smallest part of process and combining of them creates an operation. The process action can be imagined as: open a valve, start mixing etc. The process operation can be rusult of a semi-finished product processes.[5] The process stage defines whole process, multiple processes can be running in one time. The top one in a process model is the process and it defines all under it. It means all from entering a raw material to creating a final product.[3]

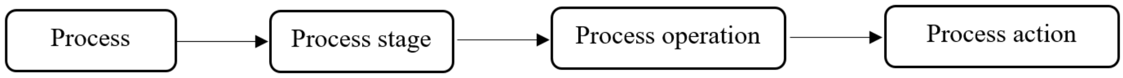

Figure 2: Process model ISA-88.

Physical model describes the process from a physical point of view of a factory. The most important parts of this model are the process cell, unit, equipment module and control module as can be seen in Figure 3. These four parts are the lowest in a terms of hierarchy.[5] The process unit can manufacture an end product or semi-finished product. The unit represents operation or operations in one batch. The equipment module defines a group of an operations for one puropose. The control module is the lowest step in the physical model ISA-88 and defines control of a sensors and action elements (valves, engines etc.).[5]

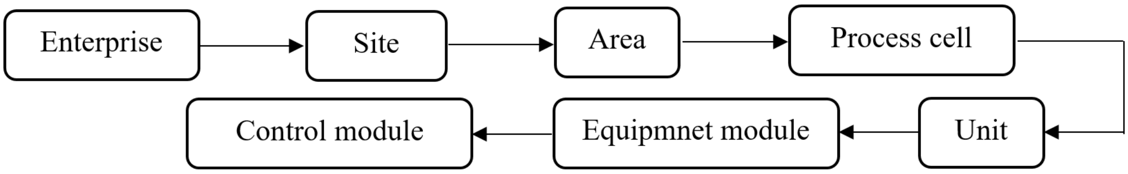

Figure 3: Physical model ISA-88.

Procedural control model is defined only in batch manufacturing. From a batch production point of view is this model the most important. As can be seen in Figure 4 on the top is the procedure. The procedure can be imagined as an icecream production - this is a procedure. This procedure has some unit procedures like cool the icecream, prepare fruit, add glaze etc. Every unit procedure has phases, this can be e.g. open valve, regulate a temperature to a setpoint and a sequence of this phases is called the operation.[3]

This can be tested in the virtual batch application, where the phases can be defined as filling, draining, mixing and heating. A higher level of controling process can be defined in MES which is defined by ISA-95.

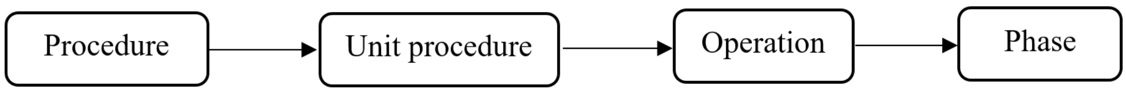

Figure 4: Procedural control model ISA-88.

5 ISA-95

The standard ISA-95 defines an interface between the control systems and enterprise level. The standard uses a several models to describe an integration of enterprise level to a factory.[2][4]

First model, the device hierarchy model, is an extension of ISA-88 physical model.

The hierarchy model of functions in the control system is second model defined by ISA-95 and it describes three different levels of enterprise: an enterptise level (bussines stuff, logistics), manufacturing operations (MES), control level.[4] In this model are defined an interfaces between each levels.[1]

The functions model and a data flows defines ten functions of the enterprise. This functions are: order management, manufacturing planning, manufacturing control, energy and material flow, buying, quality monitoring, supermarket management, costs, administration of delivery and maintenance.[2] The model defines data flows between these functions, with whom send or takes a data. There is also described a jobs of every single function.[3]

The last model is the generic model of activities, which merges some of the functions from previous model into six activities. These activities are: manufacturing, warehouse, quality, maintenance, energy and material flow and time management.[1][4]

6 CONCLUSION

In this paper is described what is the virtual manufacturing and its advantages and disadvantages. The application of virtual batch manufacturing can show alternative method to create a virtual model of a real system. With this application it is possible to test program in a PLC. Learning students in PLCs laboratory the behaviour of real system in this application, where is needed to deal with a malfunctions of system or elements is necessary preparation to real work in an industrial surroundings. After creating a control modules in PLC, there is a possibility to create the phases and control whole process from MES. In every step needs to be respected the standard ISA-88[5] and ISA-95[4] and create the functional interface between control and enterprise level by this standards.

This application will be used for education purposes in Process automatization course at BUT and could creates a better educataional surroundings to learn controlling batch processes so as useing theoretical knowledge of identifying a system and creating a regulator.

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